CHAPTER 55
The Diabetic Foot

KEY TEACHING POINTS

- The *inability* of a diabetic patient to sense the 5.07 monofilament on his or her foot modestly increases the probability of subsequent diabetic foot ulceration.
- The *ability* to sense the 5.07 monofilament decreases the probability of subsequent amputation.
- In patients with diabetic foot ulceration, ulcer size greater than 4 cm^2 or a positive probe test significantly increase probability of underlying osteomyelitis.

I. INTRODUCTION

The term *diabetic foot* refers to those complications occurring in a foot rendered hypesthetic from diabetic polyneuropathy. These include ulceration, Charcot arthropathy, and infection. Each year, 2.5% of diabetics develop a foot ulcer,[1] and the diabetic foot is the leading cause of hospitalization among diabetics and the overall leading cause of amputation in the United States.[2]

II. THE FINDINGS

A. FOOT ULCERATION

Most diabetic foot ulcers involve the forefoot, especially the toes or plantar surface of the metatarsal heads. Less often, they develop over the heel, plantar midfoot, or previous amputation sites. The term *ulcer area* refers to the product of the maximum ulcer width and maximum ulcer length.

B. DIABETIC NEUROPATHY AND SEMMES-WEINSTEIN MONOFILAMENTS

Although neuropathy, ischemia, and infection all contribute to ulceration, the most important is probably neuropathy. Nonetheless, conventional examination often fails to detect diabetic polyneuropathy, and approximately half of patients with diabetic ulceration lack complaints of numbness or pain[3] and can still detect the touch of a cotton wisp or pinprick.[4,5] Consequently, most diabetologists use a simple and more sensitive bedside tool, the Semmes-Weinstein monofilament, to identify which patients have sufficient neuropathy placing them at risk for ulceration.

According to traditional teachings, a foot that is able to sense the 5.07 monofilament* is protected from ulceration, whereas one that fails to perceive

*The nominal value of a monofilament represents the common logarithm of 10 times the force in milligrams required to bow it (e.g., the 5.07 monofilament will buckle with 11.8 g of pressure, $\log_{10}(10 \times 11{,}800) = 5.07$).[6] Therefore monofilaments with higher numbers are stiffer and more easily perceived than those with lower numbers.

the 5.07 monofilament is predisposed to ulceration. To use the monofilament, the patient should be lying supine with eyes closed, and the monofilament should be applied perpendicular to the skin with enough force to buckle it for approximately 1 second. The patient responds "yes" each time he or she senses the monofilament as the clinician randomly tests each site on the foot multiple times. In clinical studies, anywhere from 1 to 10 different sites on the foot are tested, but each study defines the abnormal result as inability to consistently sense the monofilament at *any* site. Testing the plantar surface of the first and fifth metatarsal heads may be the most efficient and overall accurate bedside maneuver.[7]

Monofilaments were first developed in 1898 by von Frey, who glued thorns to hairs of various stiffness and calibrated them with a chemical balance (**von Frey hairs**).[6] Nylon monofilaments were introduced in 1960 by Josephine Semmes and Sidney Weinstein, who used filaments of 20 different diameters (from 0.06 to 1.14 mm) to study sensation in patients with penetrating brain injuries.[8,9] Although the 5.07 monofilament is firmly entrenched as the standard for testing diabetic feet, this is based on an older study of patients with neuropathic foot ulcers from diabetes or leprosy, which used only 3 of the 20 monofilaments available.[10] The monofilaments studied were the 4.17 monofilament, which was selected because virtually all normal persons are able to sense it, and the stiffer 5.07 and 6.10 monofilaments. In the study, none of the patients with ulcers could sense the 4.17 or 5.07 monofilaments, although some could sense the 6.10 monofilament. These findings led the investigators to conclude that the ability to sense the 5.07 monofilament was protective (i.e., 6.10 was not protective and 4.17 was normal sensation). However, it is also possible that a better indicator of protective sensation is one of the other seven monofilaments between 6.10 and 4.17 not used in the study, and in support of this hypothesis, one study has suggested that the 4.21 monofilament may be a better discriminatory threshold.[4]

C. CHARCOT JOINT

Charcot joint (neuroarthropathy) refers to accelerated degenerative changes and ultimate joint destruction that follows repetitive trauma to insensitive, neuropathic joints. Although historically the most common causes were syphilis (affecting the larger joints of the lower extremity) and syringomyelia (affecting the larger joints of the upper extremity), the most common cause currently is diabetes. In diabetic patients, Charcot joint characteristically affects the foot, including ankle, tarsometatarsal, and metatarsophalangeal (MTP) joints.[11,12]

Most patients present with a limp, difficulty putting on shoes, or soft tissue swelling suggesting fracture, acute arthritis, or sprain.[12,13] The characteristic physical findings are anesthetic or hypesthetic feet (100% of patients), bony deformities (69% of patients), and soft tissue swelling (17% of patients). Many patients also have ulceration and abnormal callus formation. The most common bony deformities are abnormal projections on the plantar arch (rocker sole) or other unusual prominence of the dorsal or medial arches of the midfoot or the MTP joint. In the acute phase, soft tissue swelling typically appears at the ankle and midfoot, sometimes with marked rubor and warmth, mimicking arthritis or cellulitis (in one study, the affected foot was approximately 5°C [9.2°F] warmer than the unaffected foot).[13]

Jean-Martin Charcot described Charcot neuroarthropathy in 1868 in patients with tabes dorsalis,[14] although he credited the American Mitchell (1831) with the original description.[15]

D. OSTEOMYELITIS

In diabetic patients with foot ulceration and underlying radiographic abnormalities of the bone, it is very difficult to distinguish Charcot foot from osteomyelitis. One proposed test is the **probe test**, in which the clinician gently probes the ulcer base with a sterile, blunt, 14.0-cm, 5-Fr, stainless-steel eye probe. The test is positive, suggesting osteomyelitis, if the clinician detects a rock-hard, often gritty structure at the ulcer base without any intervening soft tissue.[16]

III. CLINICAL SIGNIFICANCE

A. THE SEMMES-WEINSTEIN MONOFILAMENT

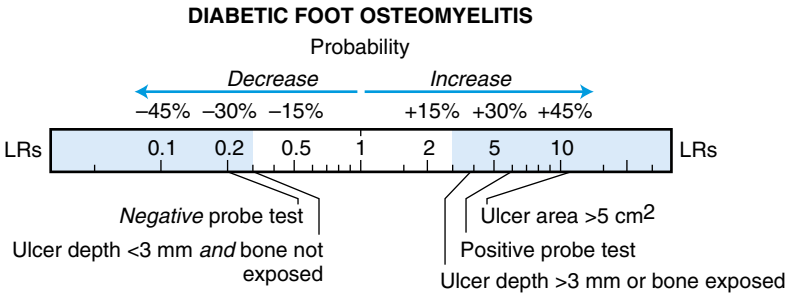
According to the information presented in EBM Box 55.1, the *inability* to feel the 5.07 monofilament is a modest predictor of ulceration during 2 to 4 years of follow-up (likelihood ratio [LR] = 2.6). Two studies have demonstrated that the *presence* of 5.07 monofilament sensation *decreases* probability of subsequent amputation during 3 to 4 years of follow-up (LR = 0.3).[17,34] Monofilament sensation predicts

EBM BOX 55.1
*The Diabetic Foot**

Finding (Reference)†	*Sensitivity (%)*	*Specificity (%)*	Likelihood Ratio‡ if Finding Is *Present*	Likelihood Ratio‡ if Finding Is *Absent*
Predictors of Subsequent Foot Ulceration				
Insensate to 5.07 monofilament[17-24]	50-90	34-86	2.6	0.5
Predictors of Osteomyelitis, in Patients With Foot Ulcers				
Ulcer area[25-27]				
>2 cm^2	44-88	20-92	NS	NS
>3 cm^2	79	77	**3.5**	**0.3**
>4 cm^2	67	91	**7.3**	0.4
>5 cm^2	50	95	**11.0**	0.5
Positive probe test[16,26,28-32]	38-98	78-93	**6.0**	**0.2**
Ulcer depth >3 mm or bone exposed[26,27]	65-82	77-85	**3.9**	**0.3**
Erythema, swelling, purulence[26,27]	36-41	77-80	NS	NS
Predictors of Nonhealing Wound at 20 Weeks, in Patients With Foot Ulcers[33]				
0 findings	14	70	0.5	—
1 finding	37	—	0.8	—
2 findings	35	—	1.8	—
3 findings	13	96	**3.5**	—

Continued

*Diagnostic standard: for *foot ulceration,* the appearance of an ulcer during 2 to 4 years of follow-up; for *osteomyelitis,* biopsy of the bone (histology or microbiology); a small number of patients in two studies[25,30] underwent magnetic resonance imaging (MRI) to confirm osteomyelitis.
†Definition of findings: for positive probe test, ulcer area, and predictors of nonhealing wound, see text.
‡Likelihood ratio (LR) if finding present = positive LR; LR if finding absent = negative LR.
NS, Not significant.
Click here to access calculator



complications better than other quantitative measures of sensation, including the 128-Hz tuning fork[35] and graded vibratory or thermal stimuli.[4,36]

B. OSTEOMYELITIS

In diabetic patients with foot ulceration, three findings *increase* the probability of underlying osteomyelitis (defined by bone biopsy): ulcer size (>3 cm^2, LR = 3.5; >4 cm^2, LR = 7.3; >5 cm^2, LR = 11), positive probe test (LR = 6), and ulcer depth greater than 3 mm or exposed bone (LR = 3.9). The findings of erythema, swelling, or purulence are unhelpful in diagnosing osteomyelitis.[27] The negative probe-to-bone test decreases probability of osteomyelitis (LR = 0.2).

C. PREDICTORS OF NONHEALING WOUNDS

In one study of more than 27,000 diabetic foot ulcers treated with debridement, moist wound dressings, and measures to reduce pressure on the foot (e.g., special footwear, crutches, or wheelchairs), 53% failed to heal after 20 weeks.[33] This study identified three independent predictors of nonhealing ulcers: (1) wound age of more than 2 months,[2] wound size of more than 2 cm^2, and (3) full-thickness wound associated with either exposed tendons, exposed joint, abscess, osteomyelitis, necrotic tissue, or limb gangrene.[33] The presence of all three of these predictors increases the likelihood that a diabetic foot ulcer will not heal by 20 weeks (LR = 3.5).

The references for this chapter can be found on www.expertconsult.com.

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